DECLARATION

I, Reiko IWAMOTO, a subject of Japan residing at 1-2-5-303, Honmachi Higashi, Cyuo-ku, Saitama-shi, Saitama-ken, 338-0003 Japan, solemnly and sincerely declare:

That I have thorough knowledge of Japanese and English languages; and

That the attached pages contain a correct translation into English of the specification of the following Japanese Patent Application:

APPLICATION NUMBER	DATE OF APPLICATION
2003-046068	February 24, 2003

I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further, that these statements are made with the knowledge that willful false statements and the like so made, are punishable by fine or imprisonment, or both, under Section 1001, Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signed this 23rd day of August, 2005

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[Name of Document] Application for Patent

[Reference No.] DP030031

[Date of Filing] February 24, 2003

[Addressee] Commissioner of the Patent Office

[Int. Cl.] H01G 4/12

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[Prepayment Registration No.] 004776

[Amount of Payment] 21000

[List of Documents Attached]

[Name of Document]	Specification	1
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[No. of General Power of Attorney] 9004892

[Proof] Required

[Name of Document] SPECIFICATION

[Title of the Invention] METHOD FOR MANUFACTURING CERAMIC ELECTRONIC COMPONENT AND GRAVURE PRINTING METHOD

[Claims]

[Claim 1] A method for manufacturing a ceramic electronic component, comprising:

a step of preparing a long composite sheet including a supporting film and a ceramic green sheet disposed on the supporting film;

a first gravure-printing step of applying first paste to the ceramic green sheet in a first region in a print region of the ceramic green sheet by gravure printing; and

a second gravure-printing step of applying second paste to the ceramic green sheet in a second region in the print region of the ceramic green sheet by gravure printing,

wherein a first print mark is formed on the ceramic green sheet in the first gravure-printing step,

wherein the position of the first print mark formed in the first gravure-printing step is compared with a desired position of the first print mark, and

wherein the second gravure-printing step is performed in accordance with the result of the comparison such that the difference between the positions of the first print mark and a second print mark is equal to a desired difference between the positions of the first and the second print

marks.

[Claim 2] A method for manufacturing the ceramic electronic component according to Claim 1, wherein the second gravure-printing step is performed after the ceramic green sheet is moved along the width and/or the length thereof in accordance with the result of the comparison or while the ceramic green sheet is being moved along the width and/or the length thereof in accordance with the result of the comparison.

[Claim 3] A method for manufacturing the ceramic electronic component according to one of Claims 1 and 2, wherein a first imaging device and a first image-processing device are used for determining the position of the first print mark.

[Claim 4] A method for manufacturing the ceramic electronic component according to one of Claims 1 to 3, wherein the second print mark is formed on the ceramic green sheet in the second gravure-printing step,

wherein the positions of the first and the second print marks formed in the first and the second gravure-printing steps, respectively, are compared with desired positions of the first and the second print marks, and

wherein the second gravure-printing step is repeated in accordance with the result of the comparison.

[Claim 5] A method for manufacturing the ceramic

electronic component according to one of Claims 1 to 3, wherein a second print-mark-printing element provided on a plate cylinder used in the second gravure-printing step is detected for determining the position of the second print mark to be formed on the ceramic green sheet.

[Claim 6] A method for manufacturing a ceramic electronic component, comprising:

a step of preparing a long composite sheet including a supporting film and a ceramic green sheet disposed on the supporting film;

a first gravure-printing step of applying first paste to the ceramic green sheet in a first region in a print region of the ceramic green sheet by gravure printing; and

a second gravure-printing step of applying second paste to the ceramic green sheet in a second region in the print region of the ceramic green sheet by gravure printing,

wherein a first print mark is formed on the ceramic green sheet in the first gravure-printing step,

wherein the transit time of the first print mark formed in the first gravure-printing step is compared with a desired transit time of the first print mark, and

wherein the second gravure-printing step is performed in accordance with the result of the comparison such that the difference between the transit times of the first print mark and a second print mark is equal to a desired

difference between the transit times of the first and the second print marks.

[Claim 7] A method for manufacturing the ceramic electronic component according to Claim 6, wherein the second gravure-printing step is performed after the ceramic green sheet is moved along the width and/or the length thereof in accordance with the result of the comparison or while the ceramic green sheet is being moved along the width and/or the length thereof in accordance with the result of the comparison.

[Claim 8] A method for manufacturing the ceramic electronic component according to one of Claims 6 and 7, wherein a first sensor and a first measuring device are used for determining the transit time of the first print mark.

[Claim 9] A method for manufacturing the ceramic electronic component according to one of Claims 1 to 8, wherein the dimension of the first print mark and/or the second print mark along the length of the ceramic green sheet changes along the width of the ceramic green sheet.

[Claim 10] A method for manufacturing the ceramic electronic component according to one of Claims 1 to 9, wherein one and the other of the first paste and the second paste are conductive paste and step-reducing ceramic paste, respectively, or both of the first paste and the second paste are conductive paste.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to methods for manufacturing ceramic electronic components such as multilayer capacitors, and more specifically relates to a method for manufacturing a ceramic electronic component including an improved gravure-printing step in which conductive paste is printed on a ceramic green sheet.

[0002]

[Description of the Related Art]

In a manufacturing process of, for example, a multilayer ceramic capacitor, a gravure-printing method is used for printing ceramic paste and conductive paste on a ceramic green sheet disposed on a supporting film.

[0003]

Patent Document 1 shown below discloses a method for manufacturing a multilayer ceramic capacitor in which a plurality of internal electrode patterns are formed on a dielectric green sheet disposed on a long supporting film by gravure printing using a first gravure roll and a step-reducing dielectric pattern is formed so as to fill the spaces between the internal electrode patterns by gravure printing using a second gravure roll.

[0004]

In the above-described method in which the internal electrode patterns and the step-reducing dielectric pattern are formed on the long dielectric green sheet using the gravure rolls, a displacement along the width of the dielectric green sheet (displacement in a direction perpendicular to the conveying direction of the dielectric green sheet) often occurs.

[0005]

In the case in which the internal electrode patterns and the step-reducing dielectric pattern are printed on the dielectric green sheet as described above, when the displacement along the width of the dielectric green sheet occurs, the internal electrode patterns and the step-reducing dielectric pattern cannot be formed at desired positions since the internal electrode patterns and the step-reducing dielectric pattern overlap each other or intervals between them excessively increase.

[0006]

Therefore, the displacement along the width of the dielectric green sheet is corrected before the second gravure-printing step by moving the second gravure roll along its axis, that is, along the width of the dielectric green sheet.

[0007]

[Patent Document 1]

Japanese Unexamined Patent Application Publication No. 8-250370

[0008]

[Problems to be Solved by the Invention]

Therefore, as shown in Fig. 17, a distorted step-reducing dielectric pattern 101b is generated depending on the time at which a gravure roll is moved. With reference to Fig. 17, reference numeral 102 denotes a long dielectric green sheet 102, and a supporting film is conveyed in a direction shown by the arrow A. In addition, a print direction is shown by the arrow B, and a position at which the gravure roll is moved is denoted by C. Each of print patterns 101a, 101b, and 101c is printed by a single turn of the gravure roll.

[0009]

In addition, there is also a problem in that the thickness of the step-reducing dielectric pattern 101b changes depending on the time at which the gravure roll is moved.

When the distortion and the change in thickness of the step-reducing dielectric pattern occur as described above, the step-reducing dielectric pattern cannot serve its intended purpose, which is to eliminate the steps around the internal electrode patterns, and structural defects of the laminate such as delamination easily occur.

[0010]

In addition, similar to the above-described gravure-printing method for printing the conductive paste and the step-reducing ceramic paste in the process of manufacturing the multilayer ceramic capacitor, a multicolor gravure-printing method also has a problem in that a displacement occurs and high-definition multicolor printing is difficult.

[0011]

In view of the above-described situation, an object of the present invention is to provide a method for manufacturing a ceramic electronic component which includes a step of applying conductive paste or step-reducing ceramic paste on a sheet by gravure printing, and by which print displacement can be corrected with high accuracy and print distortion of the step-reducing ceramic paste or the conductive paste can be prevented.

[0012]

[Means for Solving the Problems]

According to the first invention of the present application, a method for manufacturing a ceramic electronic component includes a step of preparing a long composite sheet including a supporting film and a ceramic green sheet disposed on the supporting film; a first gravure-printing step of applying first paste to the ceramic green sheet in a first region in a print region of the ceramic green sheet by

gravure printing; and a second gravure-printing step of applying second paste to the ceramic green sheet in a second region in the print region of the ceramic green sheet by gravure printing. A first print mark is formed on the ceramic green sheet in the first gravure-printing step, and the position of the first print mark formed in the first gravure-printing step is compared with a desired position of the first print mark. The second gravure-printing step is performed in accordance with the result of the comparison such that the difference between the positions of the first print mark and a second print mark is equal to a desired difference between the positions of the first and the second print marks.

[0013]

In one aspect of the first invention, the second gravure-printing step is performed after the ceramic green sheet is moved along the width and/or the length thereof in accordance with the result of the comparison or while the ceramic green sheet is being moved along the width and/or the length thereof in accordance with the result of the comparison.

[0014]

In another aspect of the fist invention, a first imaging device and a first image-processing device are used for determining the position of the first print mark.

In still another aspect of the fist invention, the second print mark is formed on the ceramic green sheet in the second gravure-printing step. The positions of the first and the second print marks formed in the first and the second gravure-printing steps, respectively, are compared with desired positions of the first and the second print marks, and the second gravure-printing step is repeated in accordance with the result of the comparison.

[0015]

In still another aspect of the fist invention, a second print-mark-printing element provided on a plate cylinder used in the second gravure-printing step is detected for determining the position of the second print mark to be formed on the ceramic green sheet.

[0016]

According to the second invention of the present application, a method for manufacturing a ceramic electronic component includes a step of preparing a long composite sheet including a supporting film and a ceramic green sheet disposed on the supporting film; a first gravure-printing step of applying first paste to the ceramic green sheet in a first region in a print region of the ceramic green sheet by gravure printing; and a second gravure-printing step of applying second paste to the ceramic green sheet in a second region in the print region of the ceramic green sheet by

gravure printing. A first print mark is formed on the ceramic green sheet in the first gravure-printing step, and the transit time of the first print mark formed in the first gravure-printing step is compared with a desired transit time of the first print mark. The second gravure-printing step is performed in accordance with the result of the comparison such that the difference between the transit times of the first print mark and a second print mark is equal to a desired difference between the transit times of the first and the second print marks.

[0017]

In one aspect of the second invention, the second gravure-printing step is performed after the ceramic green sheet is moved along the width and/or the length thereof in accordance with the result of the comparison or while the ceramic green sheet is being moved along the width and/or the length thereof in accordance with the result of the comparison.

[0018]

In another aspect of the second invention, a first sensor and a first measuring device are used for determining the transit time of the first print mark.

In still another aspect of the first and second inventions, the dimension of the first print mark and/or the second print mark along the length of the ceramic green

sheet changes along the width of the ceramic green sheet.

[0019]

In still another aspect of the first and second inventions, one and the other of the first paste and the second paste are conductive paste and step-reducing ceramic paste, respectively, or both of the first paste and the second paste are conductive paste.

[0020]

[Description of the Embodiment]

An embodiment of the present invention will be described below with reference to the accompanying drawings.

[0021]

Fig. 4 is a schematic diagram showing a manufacturing apparatus of a multilayer ceramic capacitor according to the embodiment of the present invention.

In the manufacturing apparatus 1 of the multilayer ceramic electronic component, a composite sheet 2 including a supporting film composed of a synthetic resin such as polyethylene terephthalate, polypropylene, and polyethylene naphthalate and a ceramic green sheet disposed on the supporting film is conveyed as shown by the arrow B in the figure. The manufacturing apparatus 1 of the multilayer ceramic electronic component includes first and second gravure-printing units 3 and 4 which each print on one side of the composite sheet 2.

[0022]

The first gravure-printing unit 3 includes a first gravure roll 5 which serves as a plate cylinder and a first impression roll 6. As shown in Fig. 5(a), which is a perspective view of the gravure roll 5, the gravure roll 5 is cylindrical and has a print section 7a provided along the external circumference 5a of the gravure roll 5 and a predetermined gap 5b which extends along the axis of the gravure roll 5. In order to print conductive paste on the ceramic green sheet and form internal electrodes, a plurality of rectangular recesses 7b are arranged in the print section 7a in a matrix pattern such that they extend parallel to the rotating direction of the gravure roll 5. Each of the recess 7b has a plurality of cells (not shown), each cell being surrounded by a rectangular wall. The shape of the recesses 7b corresponds to that of electrodes required in the multilayer ceramic electronic component, and is not limited to rectangular. Although only one print section 7a is shown in Fig. 5(a), two or more print sections may also be provided.

[0023]

In addition to the first print section 7a, a first print-mark-printing element 7c which prints a first print mark used for correcting a displacement of the composite sheet along the conveying direction thereof, which will be

described below, is also provided on the external circumference of the first gravure roll 5. The shape of the print-mark-printing element 7c is not particularly limited. In addition, a first trigger-mark-printing element 7d is disposed in front of the print-mark-printing element 7c in the print direction.

[0024]

The composite sheet 2 passes between the gravure roll 5 and the impression roll 6 of the first gravure-printing unit 3, and the conductive paste (first paste) supplied in the recesses 7b in the print section 7a by a conductive-paste supplier (not shown) is transferred onto the composite sheet 2. Thus, gravure printing is performed. The conductive paste is obtained by mixing conductive powder of, for example, Ag, Ag-Pd, Ni, Cu, Au, etc. with an organic vehicle.

[0025]

The first gravure-printing unit 3 also includes rollers 8a to 8e which are arranged for supplying the composite sheet 2 to the position between the gravure roll 5 and the impression roll 6, and the composite sheet 2 is conveyed to the position between the gravure roll 5 and the impression roll 6 via the rollers 8a to 8e. In addition, a roller 8f is placed behind the gravure roll 5, and the composite sheet 2 on which the conductive paste is printed is conveyed to a first drying device 9 via the roller 8f. The drying device

9 includes a suitable heater, and is provided for drying the conductive paste printed on the composite sheet 2.

[0026]

In addition, rollers 10a and 10b are placed downstream of the drying device 9, and the composite sheet 2 is supplied to the second gravure-printing unit 4 after the conductive paste is dried. The second gravure-printing unit 4 includes a second gravure roll 11 and a second impression roll 12 for performing gravure printing.

[0027]

As shown in Fig. 5(b), similar to the first gravure roll 5, the second gravure roll 11 is cylindrical and has a second print section 11b provided along the external circumference 11a of the second gravure roll 11 and a predetermined gap 11g which extend along the axis of the second gravure roll 11.

[0028]

In order to print step-reducing ceramic paste on the composite sheet 2 at regions where the conductive paste is not printed, the print section 11b includes a plurality of projections 11c having approximately the same shape as the printed conductive paste at positions corresponding to the printed conductive paste and a grid-shaped groove 11d which surrounds the projections 11c and into which the step-reducing ceramic paste is supplied. Although only one print

section 11b is shown in Fig. 5(b), two or more print sections may also be provided.

[0029]

Similar to the first gravure roll 5, in addition to the second print section 11b, a second print-mark-printing element 11f which prints a second print mark used for correcting the displacement of the composite sheet along the conveying direction thereof is also provided on the external circumference 11a of the second gravure roll 11. The shape of the print-mark-printing element 11f is not particularly limited. In addition, a second trigger-mark-printing element 11e is disposed in front of the second print-mark-printing element 11f in the print direction.

[0030]

The composite sheet 2 on which the conductive paste is printed passes between the gravure roll 11 and the impression roll 12 of the second gravure-printing unit 4, and the step-reducing ceramic paste (second paste) supplied in the groove 11d in the print section 11b by a step-reducing-paste supplier (not shown) is transferred onto the composite sheet 2. Thus, gravure printing for eliminating the steps is performed. The step-reducing ceramic paste is obtained by mixing ceramic powder of, for example, dielectric ceramic, magnetic ceramic, glass, glass ceramic, etc. with an organic vehicle.

[0031]

Rollers 13a to 13e and a compensator roll 28 are arranged for supplying the composite sheet 2 to the position between the gravure roll 11 and the impression roll 12.

[0032]

The compensator roll 28 can move in a direction shown by the arrow D in Fig. 4, and the position of the ceramic green sheet along its length is controlled by moving the compensator roll 28. In addition, a roller 13f and a second drying device 14 are disposed downstream of the gravure roll 11. The construction of the second drying device 14 is similar to that of the first drying device 9. The second drying device 14 includes a heater suitable for drying the step-reducing ceramic paste applied by the second gravure roll 11.

[0033]

In addition, rollers 15a and 15b are placed downstream of the second drying device 14, and the composite sheet 2 which is subjected to the printing processes performed by the first and the second gravure printing portions 3 and 4 is output along a direction shown by the arrow C.

[0034]

As shown in Fig. 6, according to the present embodiment, the second gravure roll 11 is connected to a moving device 20 which moves the gravure roll 11 along its axis for

correcting the displacement between the conductive paste printed by the first gravure-printing unit 3 and the step-reducing ceramic paste printed by the second gravure-printing unit 4 in the width direction (direction perpendicular to the conveying direction of the composite sheet). Although not shown in Fig. 6, the moving device 20 includes a reciprocating drive source which moves the gravure roll 11 by a suitable distance along its axis in accordance with a signal input from a controller 24. The reciprocating drive source may be a reciprocating drive device such as an air cylinder and a hydraulic cylinder or a reciprocating drive mechanism obtained by combining a motor and a rack-and-pinion system.

[0035]

Fig. 2 is a schematic diagram showing the main part of a system for controlling the position of the gravure roll 11 along its axis and the position of the composite sheet 2 along its length according to the present embodiment. As shown in Fig. 2, a trigger sensor 21 and a first camera 22 are disposed in front of the second gravure roll 11. The trigger sensor 21 is provided for detecting a first trigger mark, and the camera 22 is provided for photographing a first print mark. The trigger sensor 21 and the first camera 22 are connected to a first image processor 23, and the first image processor 23 is connected to the controller

24.

[0036]

When the trigger mark is detected by the trigger sensor 21, the controller 24 outputs a command to photograph the first print mark to the camera 22. Then, an image of the first print mark obtained by the camera 22 is processed by the image processor 23, and a signal indicating the position of the first print mark is input to the controller 24.

[0037]

In addition, a trigger sensor 25, a second camera 26, and a second image processor 27 are disposed downstream of the second gravure roll 11. The trigger sensor 25 is provided for detecting a second trigger mark printed by the second gravure roll 11, and the camera 26 is provided for photographing a second print mark. The image processor 27 is connected to the controller 24. When the controller 24 receives a signal indicating that the second trigger mark is detected by the trigger sensor 25 after the second gravure-printing step, the controller 24 drives the second camera 26 such that it photographs the second print mark. An image photographed by the second camera 26 is processed by the image processor 27, and a signal indicating the position of the second print mark is input to the controller 24.

[0038]

The controller 24 stores desired positions of the first

and the second print marks, that is, desired positions of the first and the second print marks along the length and width of the ceramic green sheet.

[0039]

Next, a method for manufacturing a multilayer ceramic electronic component according to the present embodiment will be described below with reference to Figs. 1(a) to 1(c) and Figs. 3(a) and 3(b) in addition to the above-mentioned drawings.

Fig. 1(a) is a schematic plan view of the composite sheet after the first and the second gravure-printing steps are performed. A plurality of print patterns 32 are printed in a print region of the composite sheet 2 including the supporting film and the ceramic green sheet by the first and the second gravure-printing steps. A first trigger mark 33, a first print mark 34, a second trigger mark 35, and a second print mark 36 are printed at the side of the print region. The first and the second trigger marks 33 and 35 are printed in front of the first and the second print marks 34 and 36, respectively.

[0040]

The first trigger mark 33 and the first print mark 34 are printed in the first gravure-printing step. As shown in Fig. 1(b), only the first print mark 34 is printed after the first printing step. The second trigger mark 35 and the

second print mark 36 are printed in the second gravure-printing step.

[0041]

As shown in Fig. 2, in the present embodiment, the position of the first print mark 34 is determined by the image processor 23 after the first gravure-printing step and before the second gravure-printing step. More specifically, when the first trigger mark 33 is detected by the trigger sensor 21, the controller 24 drives the first camera 22 such that it photographs the first print mark 34. Then, the actual position of the first print mark 34 is input to the controller 24.

[0042]

The controller 24 calculates the difference between the actual position of the first print mark 34 which is determined as above and the desired position thereof which is stored in the controller 24 in advance, and moves the composite sheet 2 on the basis of the calculated difference such that the distances q and r between the first and the second print marks 34 and 35 along the width and the length, respectively, shown in Fig. 1(c) become the same as desired distances Q and R, respectively. The movement of the composite sheet 2 is achieved by the above-described moving device 20 and the compensator roll 28. More specifically, the movement along the width of the ceramic green sheet is

achieved by the above-described moving device 20 and the movement along the length thereof is achieved by adjusting the position of the compensator roll 28 so as to eliminate the difference along the length.

[0043]

Accordingly, the composite green sheet is moved such that the positional relationship between the first and the second print marks is optimized before the second gravure-printing step is performed. More specifically, even when the first print mark is displaced from the desired position, the second mark is printed at an accurate position with respect to the first print mark. Therefore, in the second gravure-printing step which is performed afterwards, print patterns can be formed at suitable positions with high accuracy with respect to print patterns formed in the first gravure-printing step. More specifically, the displacements between the print patterns formed in the first gravure-printing step and those formed in the second gravure-printing step can be reliably prevented.

[0044]

Although the ceramic green sheet is moved by the moving device 20 and the compensator roll 28 before the second gravure-printing step in the present embodiment, it may also be moved during the second gravure-printing step. More specifically, the ceramic green sheet may be moved in the

middle of the second gravure printing so that the accuracy can be increased in the second gravure-printing step which is performed afterwards. In particular, in the case in which a plurality of print patterns are printed along the length in the second gravure-printing step, distortion of the print patterns printed in the second gravure-printing step can be prevented by moving the ceramic green sheet within the regions between the print patterns.

[0045]

In the present embodiment, however, the second gravure-printing step using the gravure roll 11 is performed after the ceramic green sheet is moved.

In the second gravure-printing step, the second trigger mark 35 and the second print mark 36 shown in Fig. 1(a) are printed. When the second trigger mark 35 is detected by the trigger sensor 20 at a position downstream of the second gravure roll 11, the controller 24 drives the camera 26 such that it photographs the second print mark 36. Then, the position of the second print mark 36 is determined by the image processor 27, and is input to the controller 24.

[0046]

The desired position of the second print mark is stored in the controller 24 in advance. The controller 24 compares the positions of the first and the second print marks which are actually printed in the first and the second gravure-

printing steps, respectively, with the desired positions of the first and the second print marks stored in advance, and moves the ceramic green sheet so as to eliminate the differences between them.

[0047]

Since the ceramic green sheet is moved after the second gravure-printing step so as to eliminate the differences between the positions of the first and the second print marks which are actually printed and the desired positions of the first and the second print marks stored in advance, the accuracy in the first and the second gravure-printing steps performed afterwards can be increased. In the present invention, however, the feedback control using the second print mark is not necessary, and only the feedforward control using the first print mark may be performed.

[0048]

In the present embodiment, the distances between the first and the second print marks 34 and 36 along the width and the length are reliably adjusted to the desired distances Q and R, respectively, by moving the gravure roll 11 along the width of the ceramic green sheet with the moving device 20 and adjusting the position of the compensator roll 28. Accordingly, as shown in Figs. 7 and 8, in the second gravure-printing step which is performed afterwards, the print patterns can be printed at accurate

positions with respect to the print patterns formed in the first gravure-printing step. In other words, the conductive paste and the step-reducing ceramic paste can be accurately printed such that they do not overlap each other.

[0049]

As shown in Fig. 8, in the composite sheet 2 which is subjected to the above-described first and second gravure-printing steps, a ceramic green sheet 72 is formed on a supporting film 71. In addition, internal electrodes 73 are formed on the ceramic green sheet 72 in the first gravure-printing step, and a step-reducing ceramic member 74 is formed in the second gravure-printing step. Although the internal electrodes 73 and the step-reducing ceramic member 74 are arranged without gaps therebetween in Fig. 8, predetermined gaps may also be provided between the internal electrodes 73 and the step-reducing ceramic member 74. Alternatively, the step-reducing ceramic member 74 may also be formed such that it overlaps the internal electrodes 73 at the peripheral edges of the internal electrodes 73 by a predetermined width.

[0050]

The long composite sheet 2 is cut by a cutting head (not shown) such that a film element including the ceramic green sheet 72, the internal electrodes 73, and the step-reducing ceramic member 74 is separated from the supporting

film 71. Then, a plurality of film elements obtained as above are laminated on a lamination stage or in the cutting head, so that a mother laminate 81 shown in Fig. 9(a) is obtained. In the mother laminate 81, a plain ceramic green sheet is provided at the bottom. In addition, another plain ceramic green sheet may also be provided on the top.

[0051]

In addition, the mother laminate 81 may also be formed by repeating processes of cutting the long composite sheet along the print section such that a card-shaped sheet element is obtained, pressing the card-shaped sheet element onto a plain ceramic green sheet placed on a lamination stage such that the supporting film 71 faces upward, and removing the supporting film.

[0052]

Then, laminate units are obtained by cutting the mother laminate 81 along its thickness, each laminate unit being used in a single multilayer ceramic capacitor, and a sintered ceramic component 92 shown in Fig. 8(b) is obtained by sintering each of the laminate units. Then, a multilayer ceramic capacitor 91 is obtained by forming external electrodes 93 and 94 on the ends of the sintered ceramic component 92. The laminate unit and the external electrodes may also be sintered simultaneously.

[0053]

In the manufacturing method of the multilayer ceramic capacitor 91, the conductive paste and the step-reducing ceramic paste are printed as described in the above embodiment. Therefore, displacements between the conductive paste and the step-reducing ceramic paste can be reduced and the steps around the conductive-paste elements may be reliably eliminated.

[0054]

Therefore, structural defects of the sintered components such as delamination does not easily occur and the defect rate can be effectively reduced.

The present invention may be applied not only to the multilayer ceramic capacitor but also to various multilayer ceramic electronic components such as a multilayer inductor, a multilayer noise filter, a multilayer LC filter, and a multilayer composite module. In such a case, circuit elements can be obtained by forming via holes in the ceramic green sheet and connecting the planar internal electrode patterns.

[0055]

(First Modification)

A method for manufacturing a multiplayer ceramic electronic component according to a first modification of the first embodiment will be described below with reference to Figs. 10 to 12. The constructions of the first

modification and second and third modifications, which will be described below, are similar to that of the first embodiment except for the structure for determining the position of the second print mark after the second gravure-printing step. Therefore, only differences from the first embodiment will be described below and explanations of constructions similar to that of the first embodiment will be omitted.

[0056]

As shown in Fig. 10, a trigger sensor 41 and a camera 42 are connected to the image processor 27. The trigger sensor 41 is provided for detecting the trigger-mark-printing element 11e on the second gravure roll 11, and the camera 42 is provided for photographing the second print-mark-printing element 11f on the second gravure roll 11. More specifically, in the present modification, the position of the second print-mark-printing element 11f is determined using the trigger-mark-printing element 11e and the second print-mark-printing element 11f instead of using the second trigger mark and the second print mark printed on the composite sheet. Then, the position of the second print-mark-printing element 11f is input to the controller 24.

[0057]

Also in the present modification, the controller 24 stores desired positions of the first and the second print

marks.

In the present modification, the first print mark 34 is printed on the composite sheet, as shown in Fig. 11, and the position of the first print mark 34 is input to the controller 24 as in the first embodiment.

[0058]

Similar to the first embodiment, the controller 24 moves the ceramic green sheet such that the second print mark is printed at a position where the distances between the first and the second print marks along the width and the length are Q and R, respectively, on the basis of the position of the first print mark 34 which is actually printed. Accordingly, the ceramic green sheet is moved to a suitable position before the second gravure-printing step. Therefore, also in the second embodiment, even when print patterns printed in the first gravure-printing step are displaced, print patterns printed in the second gravure-printing step can be suitably positioned with respect to the print patterns printed in the first gravure-printing step.

[0059]

Next, when the trigger sensor 41 detects the second trigger-mark-printing element 11e in the second gravure-printing step, the second print-mark-printing element 11f shown in Fig. 12 is photographed by the camera 42 and the position information thereof is input to the controller 24.

In addition, the time at which the second print-mark-printing element 11f is photographed is also input to the controller 24. The controller 24 calculates the position of the second print mark on the basis of the received position information and the time.

[0060]

In the present modification, similar to the first embodiment, the ceramic green sheet is moved so as to eliminate the differences between the desired positions of the first and the second print marks which are stored in the controller 24 in advance and the positions of the first and the second print marks which are actually printed before the second gravure-printing step is performed next.

[0061]

Accordingly, in the second gravure-printing step which is performed afterwards, the print patterns can be printed at accurate positions with respect to the print patterns printed in the first gravure-printing step.

In addition, since the positions of the second trigger mark and the second print mark are determined using the trigger-mark printing element 11e and the second print-mark-printing element 11f provided on the second gravure roll 11 instead of using the second trigger mark and the second print mark printed on the composite sheet, the image process can be performed irrespective of the material of the second

trigger mark and the second print mark.

[0062]

For example, when the second trigger mark and the second print mark are composed of the same ceramic material as the ceramic green sheet in the composite sheet, the image process of the second trigger mark and the second print mark printed on the composite sheet is often difficult. However, when the image process of the trigger-mark-printing element 11e and the second print-mark-printing element 11f is performed, the comparison between the second gravure roll 11 and the trigger-mark-printing element 11e and between the second gravure roll 11 and the second print-mark-printing element 11f can be performed irrespective of the material of the trigger mark and the print mark.

[0063]

The positions of the trigger-mark-printing element 11e and the second print-mark-printing element are the same as the positions of the second trigger mark and the second print mark printed on the composite sheet unless displacement occurs due to sliding between the second gravure roll 11 and the composite sheet.

[0064]

(Second Modification)

A second modification of the first embodiment will be described below with reference to Figs. 13 to 17.

In the second modification, as shown in Fig. 14, which is a plan view of the composite sheet after the second gravure-printing step, a first print mark 51 and a second print mark 52 are printed outside the print area after the first and the second gravure-printing steps.

[0065]

The dimensions of the first and the second print marks 51 and 52 along the length of the composite sheet 2 change depending on the position along the width of the composite sheet. More specifically, the dimensions of the first and the second print marks 51 and 52 along the length of the composite sheet increases toward the center of the composite sheet. Accordingly, each of the first and the second print marks 51 and 52 has the shape of a triangle with its base facing the center of the composite sheet.

[0066]

In addition, as shown in Fig. 13, a first sensor 53 and a first time-measuring device 54 are placed in front of the second gravure roll 11. The first sensor 53 is turned on while the first print mark 51 is passing by the first sensor 53. The first time-measuring device 54 measures the time interval during which the first sensor 53 is turned on. More specifically, the first time-measuring device 54 measures the transit time of the first print mark 51, that is, the time interval during which the first print mark 51

passes by the first sensor 53, and inputs the time interval to the controller 24. In addition, the time at which the first sensor 53 is turned on is also input to the controller 24.

[0067]

In addition, a second sensor 55 and a second time-measuring device 56 are disposed behind the second gravure roll 11. The second sensor 55 is constructed similarly to the first sensor 53, and is turned on while the second print mark 52 is passing by the second sensor 55. Accordingly, the controller 24 receives the transit time of the second print mark 52, that is, the time interval during which the second print mark 52 passes by the second sensor 55 from the second time-measuring device 56. In addition, the time at which the second sensor 55 is turned on is also input to the controller 24.

[0068]

As described above, the dimensions of the first and the second print marks 51 and 52 along the length of the composite sheet change depending on the position along the width of the composite sheet. Therefore, the positions of the first and the second print marks 51 and 52 along the width can be determined by measuring the time intervals of the first and the second print marks 51 and 52. This will be described in more detail below with reference to Figs. 15

and 16.

[0069]

As shown in Fig. 15(a), the time interval i during which the first print mark 51 passes by the first sensor can be obtained when the first print mark 51 passes by the first sensor. In addition, as shown in Fig. 15(b), the time interval u is obtained and input to the controller 24 when the second print mark 52 passes by the second sensor. Since the first and the second print marks 51 and 52 have shapes as described above, when the controller 24 receives the time intervals i and u, the controller 24 can calculate the positions of the first and the second print marks 51 and 52 along the width of the composite sheet. Then, the distance w between the first and the second print marks 51 and 52 along the width of the composite sheet is obtained on the basis of the calculation results. The controller 24 stores a desired distance between the first and the second print marks 51 and 52 along the width obtained when the first and the second print marks 51 and 52 are accurately printed in the first and the second gravure-printing steps, respectively. Accordingly, the displacement along the width can be reliably eliminated by moving the second gravure roll 11 with the moving device so as to eliminate the difference between the actual distance between the first and the second print marks 51 and 52 and the desired distance between them.

[0070]

In addition to the displacement along the width of the ceramic green sheet, the displacement along the length thereof can also be eliminated.

More specifically, since the times at which the measurements of the time intervals i and u are started are also detected by the sensors 53 and 55, respectively, the distance v between the print marks 51 and 52 along the length can also be obtained. Accordingly, when the controller 24 stores the desired distance between the first and the second print marks 51 and 52 along the length, the position of the ceramic green sheet in the second gravure-printing step along its length can be corrected by moving the compensator roll 28 by a distance corresponding to the difference between the above-described desired distance along the length and the distance between the first and the second print marks 51 and 52 along the length which is obtained as described above.

[0071]

(Third Modification)

In the second modification, the second sensor 55 measures the time interval during which the second print mark 52 printed by the second gravure roll 11 passes by. However, as shown in Fig. 16, the second sensor may also be arranged such that it measures a time interval ua during

which a second print-mark-printing element 11h provided on the gravure roll 11 passes by. In such a case, when the relationship between the time interval 11a during which the second print-mark-printing element on the gravure roll 11 passes by and the position at which the second print mark is actually printed is determined in advance, the position at which the second print mark is printed can be determined on the basis of the time interval 11a. Other constructions of the third modification are the same as those of the second modification.

[0072]

(Other Modifications)

In the first embodiment, only one camera is arranged downstream of the gravure roll 11 for photographing the first and the second print marks. However, the first and the second print marks may also be photographed with different cameras. More specifically, two cameras may be arranged behind the second gravure roll 11 in addition to the camera for photographing the trigger mark.

[0073]

In addition, also in the second modification, two sensors for measuring the time intervals during which the first and the second print marks pass by may be arranged behind the second gravure roll 11.

[0074]

In addition, according to the present invention, only the position of the composite sheet along the width thereof may be controlled by moving the second gravure roll along its axis.

In the above-described embodiment and modifications, the first paste is the conductive paste and the second paste is the step-reducing ceramic paste. However, the first paste may also be the step-reducing ceramic paste and the second paste may also be the conductive paste. In addition, both of the first and the second pastes may also be the conductive paste. Both of the first and the second pastes are the conductive paste when, for example, electrode patterns of different shapes are formed of the first and the second pastes, a structure is formed using conductive pasts of different materials, double coating is required, etc.

[0075]

The present invention is not limited to multilayer ceramic electronic components, and may also be applied to methods for manufacturing other ceramic electronic components.

[0076]

[Advantages]

According to a method for manufacturing a ceramic electronic component of the first invention, the position of the first print mark which is actually formed in the first

gravure-printing step is compared with the desired position of the first print mark after the first gravure-printing step, and the second gravure-printing step is performed in accordance with the result of the comparison. More specifically, the second gravure-printing step is performed such that the position at which the second print mark is printed is separated from the first print mark by a desired distance between the first and the second print marks that is stored in advance. Therefore, when the first and the second pastes are applied to the ceramic green sheet in the first and the second gravure-printing steps, respectively, print patterns formed in the second gravure-printing step can be positioned with high accuracy with respect to print patterns formed in the first gravure-printing step.

[0077]

When the second gravure-printing step is performed after the ceramic green sheet is moved or while it is being moved along the width and/or the length in accordance with the difference between the position at which the first print mark is formed and the desired position of the first print mark, print patterns formed in the second gravure-printing step performed after the movement of the ceramic green sheet can be positioned with high accuracy with respect to print patterns formed in the first gravure-printing step.

[0078]

When a first imaging device and a first image-processing device are used for determining the position of the first print mark, the position of the first print mark can be determined with high accuracy.

[0079]

In the case in which the second print mark is formed on the ceramic green sheet in the second gravure-printing step, the positions of the first and the second print marks formed in the first and the second gravure-printing steps, respectively, are compared with desired positions of the first and the second print marks, and the second gravure-printing step is repeated in accordance with the result of the comparison, the position of the ceramic green sheet is adjusted by feedforward control after the first gravure-printing step. Then, the positions of the first and the second print marks are adjusted with high accuracy by feedback control after the second gravure-printing step on the basis of the actual positions of the first and the second print marks. Accordingly, the first and the second gravure-printing steps can be performed with higher accuracy.

[0080]

When the position of the second print mark formed on the ceramic green sheet is determined by detecting the second print-mark-printing element provided on a plate cylinder used in the second gravure-printing step and the

first or the second gravure-printing step is performed in accordance with the result of comparison between the desired positions of the first and the second print marks and the actual positions thereof, the positions of the first and the second print marks can be determined and compared with the desired positions more quickly since the position of the second print mark is determined by detecting the second print-mark-printing element provided on the plate cylinder. Therefore, the position of the ceramic green sheet can be adjusted more quickly for the second gravure-printing step.

[0081]

According to a method for manufacturing a ceramic electronic component of the second invention, the transit time of the first print mark that is actually formed in the first gravure-printing step is compared with a desired transit time of the first print mark and the second gravure-printing step is performed in accordance with the result of the comparison. Therefore, similar to the first invention, by performing the second gravure-printing step such that the difference between the transit times of the first and the second print marks is equal to a desired difference between the transit times of the first and the second print marks that is stored in advance, the print patterns formed in the second gravure-printing step can be positioned with high accuracy with respect to the print patterns formed in the

first gravure-printing step.

[0082]

When the second gravure-printing step is performed after the ceramic green sheet is moved or while it is being moved along the width and/or the length in accordance with the difference between the actual transit time of the first print mark and the desired transit time thereof such that the second print mark is printed after the first print mark with a time difference between the desired transit time of the first print mark and that of the second print mark, the print patterns formed in the second gravure-printing step can be positioned with high accuracy with respect to the print patterns formed in the first gravure-printing step.

[0083]

When a first sensor and a first measuring device are used for determining the transit time of the first print mark, the transit time of the first print mark can be determined with high accuracy.

[0084]

When the dimension of the first print mark and/or the second print mark along the length of the ceramic green sheet changes along the width of the ceramic green sheet, the transit times of the first and the second print marks can be easily determined with a simple sensor.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1(a) is a schematic plan view showing print patterns and first and second print marks printed in first and second gravure-printing steps, Fig. 1(b) is a schematic plan view showing the first print mark, and Fig. 1(c) is a schematic plan view showing the relationship between the first and the second print marks.

[Fig. 2]

Fig. 2 is a schematic diagram showing a device for determining the positions of the first and the second print marks according to a first embodiment of the present invention.

[Fig. 3]

Fig. 3(a) is a schematic perspective view showing a displacement of a second gravure roll along its axis.

[Fig. 4]

Fig. 4 is a schematic diagram showing an apparatus for performing the first and the second gravure-printing steps used in the first embodiment of the present invention.

[Fig. 5]

Figs. 5(a) and 5(b) are perspective views of first and second gravure rolls, respectively.

[Fig. 6]

Fig. 6 is a schematic diagram showing a device for moving the second gravure roll along its axis according to

the first embodiment.

[Fig. 7]

Fig. 7 is a schematic plan view showing the state after a ceramic green sheet disposed on a supporting film is subjected to the first and the second gravure-printing steps according to the first embodiment.

[Fig. 8]

Fig. 8 is a schematic sectional view showing the state after conductive paste and step-reducing ceramic paste are printed on the ceramic green sheet disposed on the supporting film in the first and the second gravure-printing steps according to the first embodiment.

[Fig. 9]

Fig. 9(a) is a sectional view of a mother laminate obtained in the first embodiment, and Fig. 9(b) is a sectional view of a multilayer ceramic capacitor obtained in the first embodiment.

[Fig. 10]

Fig. 10 is a schematic diagram showing a device for determining the positions of first and second print marks according to a first modification of the present invention.

[Fig. 11]

Fig. 11 is a schematic plan view of the first print mark printed in the first modification.

[Fig. 12]

Fig. 12 is a schematic plan view of the second print mark printed in the first modification.

[Fig. 13]

Fig. 13 is a schematic diagram showing a device for determining the positions of first and second print marks according to a second modification of the present invention.

[Fig. 14]

Fig. 14 is a schematic plan view showing print patterns and the first and the second print marks printed in first and second gravure-printing steps according to the second modification.

[Fig. 15]

Figs. 15(a) and 15(b) are diagrams showing steps of determining transit times of the first print mark and the second print mark, respectively, in the second modification.

[Fig. 16]

Fig. 16 is a schematic perspective view showing a step of determining a transit time of a second print-mark-printing element provided on a second gravure roll according to a third modification.

[Fig. 17]

Fig. 17 is a schematic plan view showing a step of printing conductive paste and step-reducing ceramic paste in a known method for manufacturing a ceramic electronic component.

[Reference Numerals]

2: composite sheet

3, 4: first and second gravure-printing units

5: first gravure roll

6: first impression roll

7a: first print section

7b: recess

7c: first print-mark-printing element

7d: first trigger-mark-printing element

11: second gravure roll

11a: external circumference

11e: second trigger-mark-printing element

11f: second print-mark-printing element

20: moving device

21: trigger sensor

22: first camera

23: image processor

24: controller

25: trigger sensor

26: second camera

27: image processor

28: compensator roll

32: print pattern

33: first trigger mark

34: first print mark

35: second trigger mark

36: second print mark

41: trigger sensor

42: camera

51: first print mark

52: second print mark

53: first sensor

54: first time-measuring device

55: second sensor

56: second time-measuring device

71: supporting film

72: ceramic green sheet

73: internal electrode

74: step-reducing ceramic member

81: mother laminate

91: multilayer ceramic capacitor

92: sintered ceramic component

93, 94: external electrode

JP Application No. 2003-046068

[Name of Document] ABSTRACT

[Abstract]

[Object] To provide a method for manufacturing a ceramic electronic component which includes first and second gravure-printing steps of applying conductive paste or step-reducing ceramic paste on a sheet by gravure printing, and by which print displacement can be corrected with high accuracy and print distortion can be prevented.

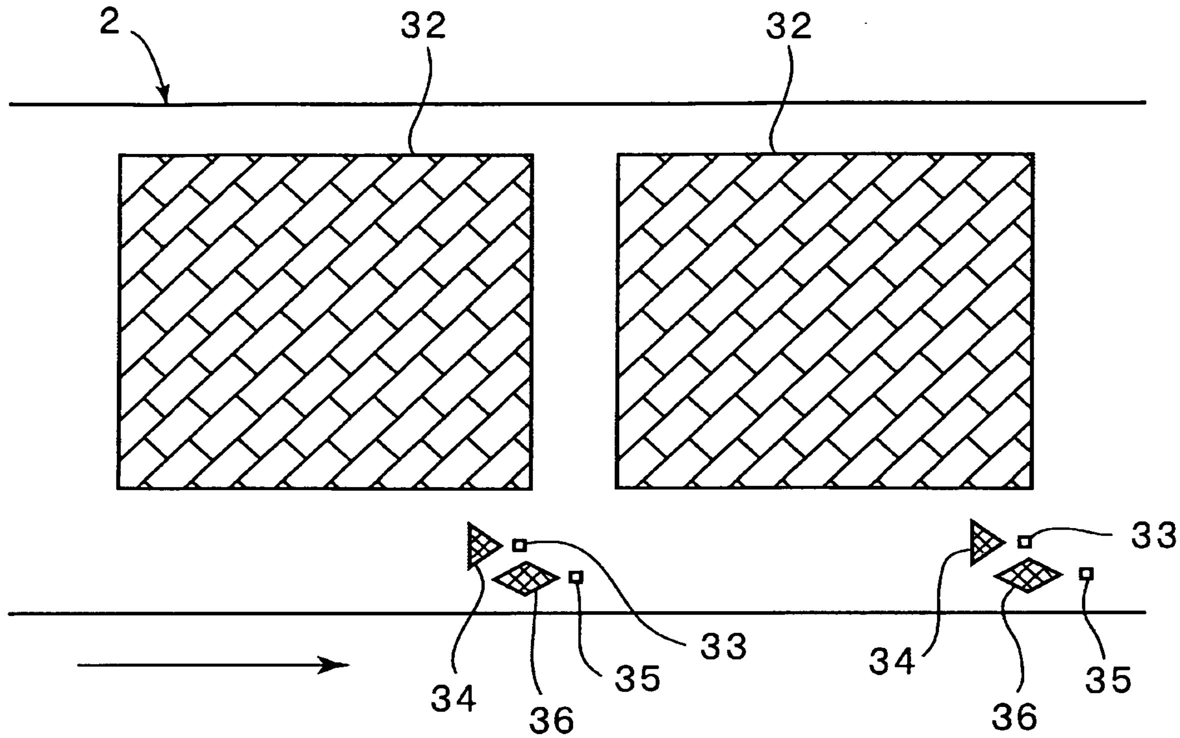
[Solving Means] A method for manufacturing a ceramic electronic component includes first and second gravure-printing steps in which conductive paste and step-reducing ceramic paste are printed on a composite sheet 2 including a ceramic green sheet. A first print mark 34 is printed before the second gravure-printing step is performed, and the position of the first print mark is determined and compared with a desired position of the first print mark stored in advance before the second gravure-printing step. Then, the second gravure-printing step is performed in accordance with the result of comparison such that a second print mark is printed at a suitable position with respect to the position of the first print mark.

[Selected Figure] Fig. 1

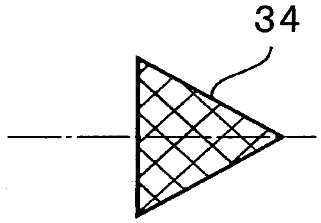
【書類名】 図面 [Name of Document] DRAWINGS

【図１】 [FIG. 1]

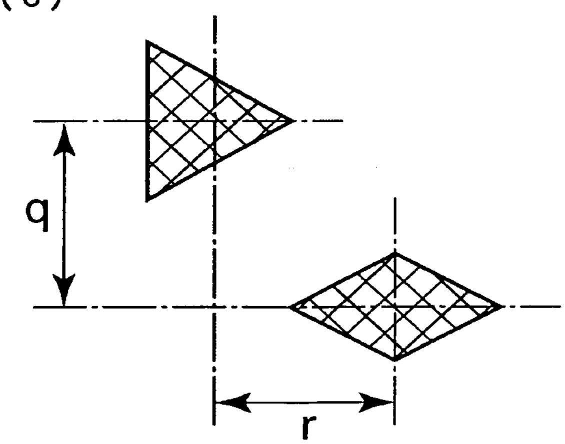
(a)



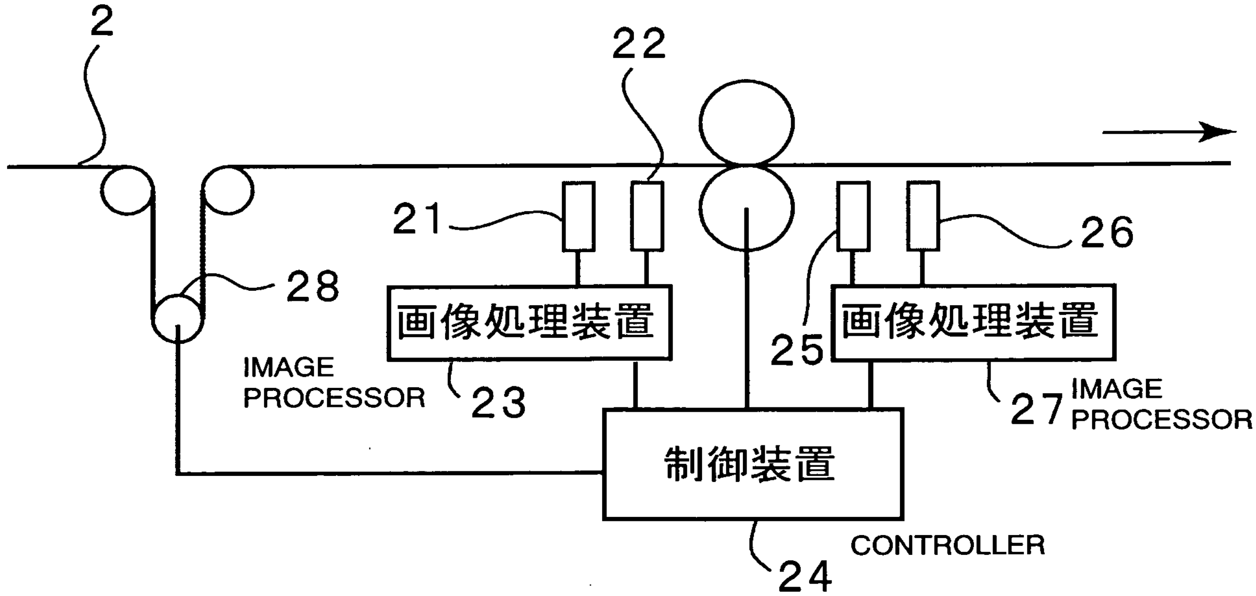
(b)



(c)



【図２】　[FIG. 2]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26
28
画像処理装置
25
画像処理装置
IMAGE
PROCESSOR
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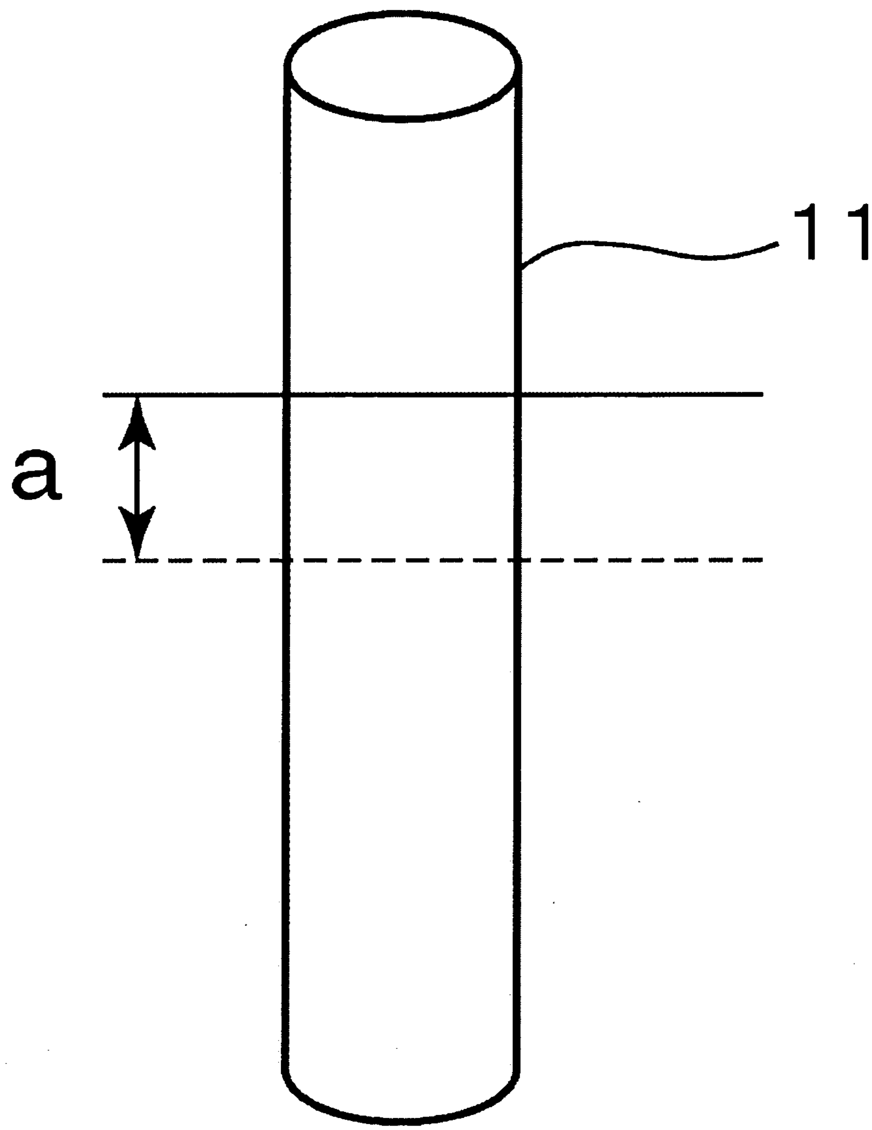
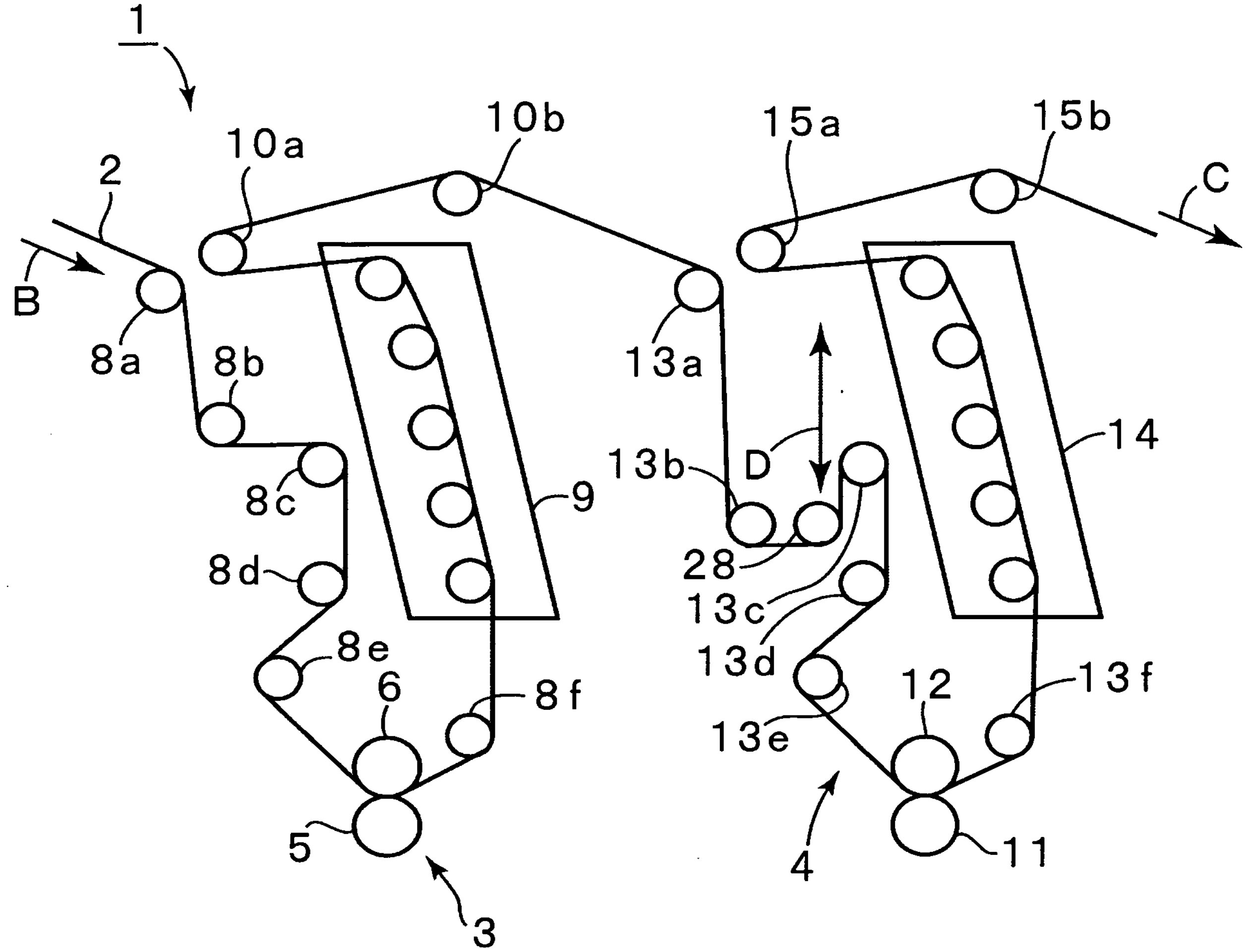
27
IMAGE
PROCESSOR
制御装置
CONTROLLER
24

【図３】 [FIG. 3]



【図４】 [FIG. 4]


1
2
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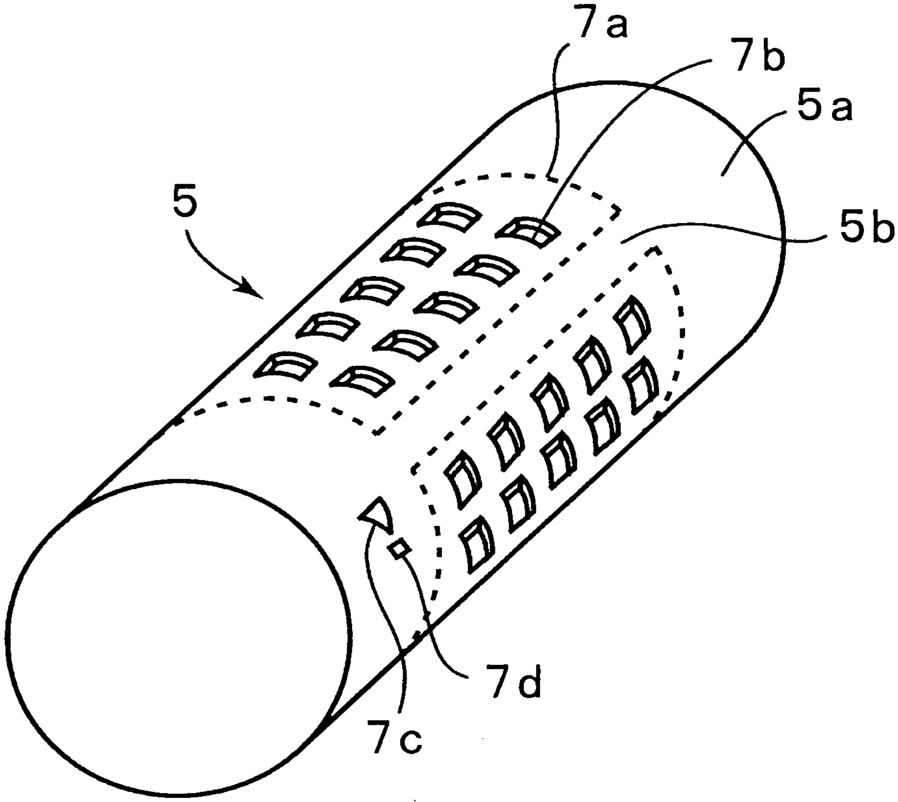
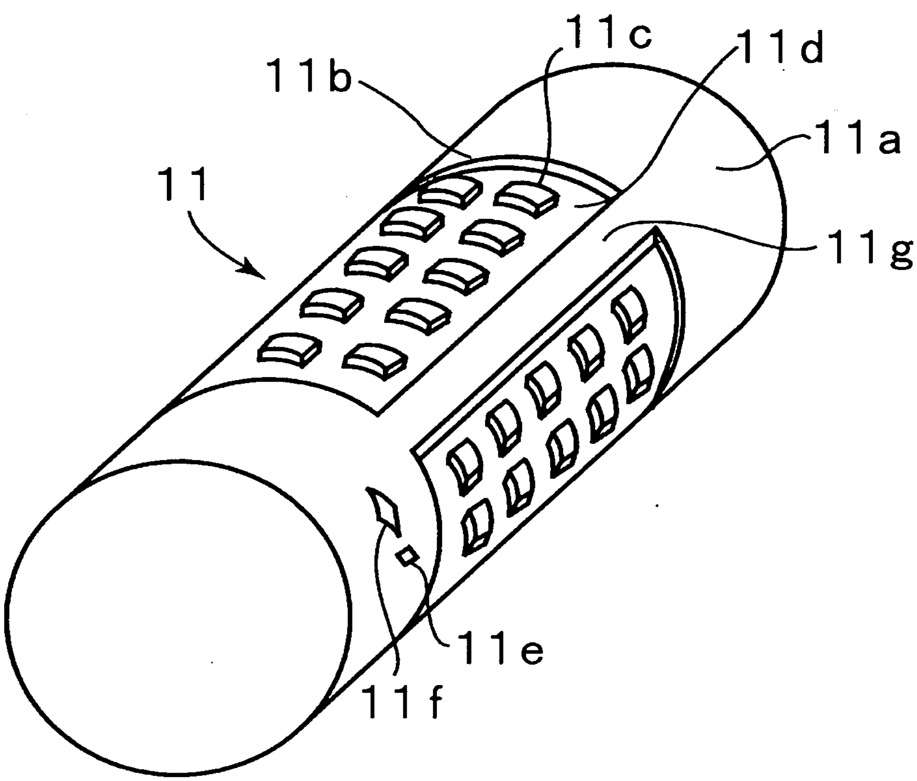
8c
8d
8e
6
8f
5
3
9
10a
10b
13a
13b
D
28
13c
13d
13e
12
13f
11
4
14
15a
15b
C

【図５】　[FIG. 5]

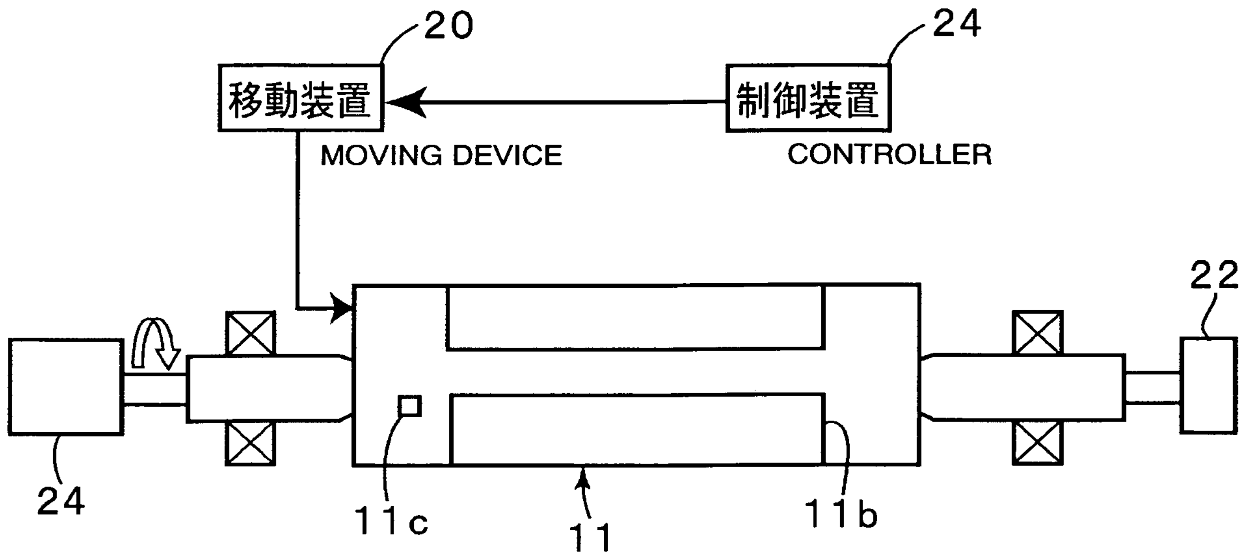
(a)



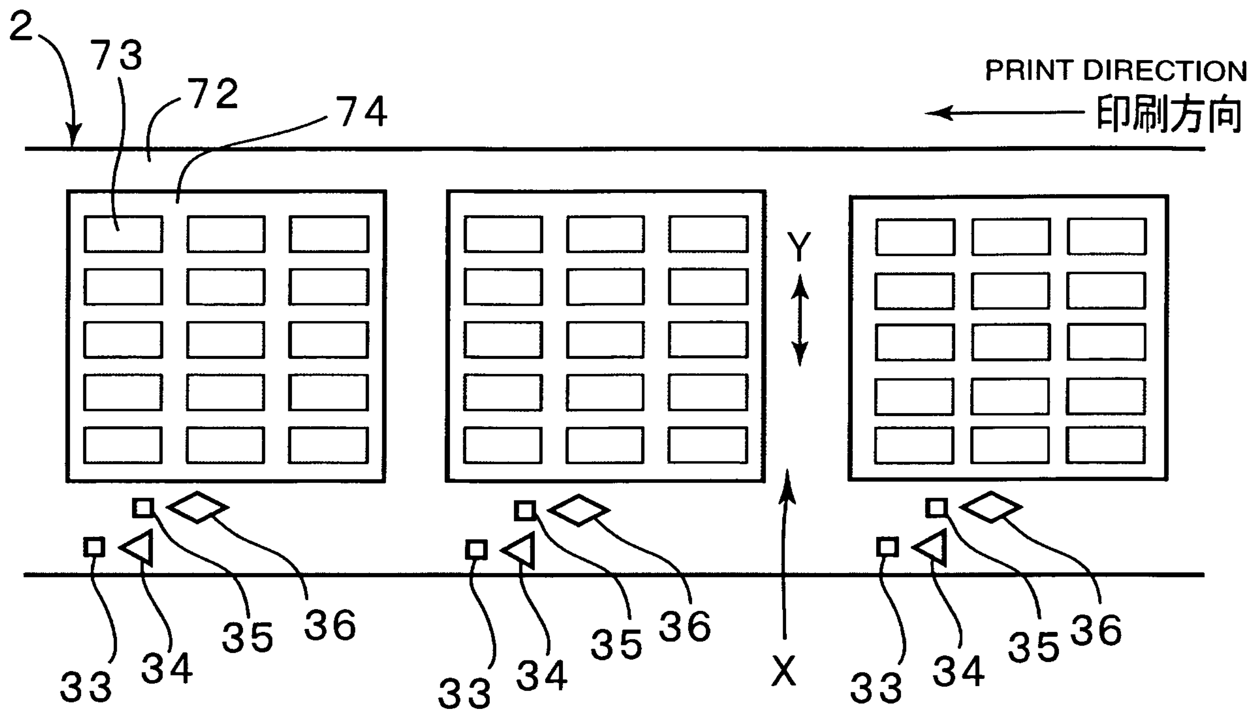
(b)



【図６】 [FIG. 6]



【図７】 [FIG. 7]


2
73
72
74
PRINT DIRECTION
印刷方向
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X
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34
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36
33
34
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36
33
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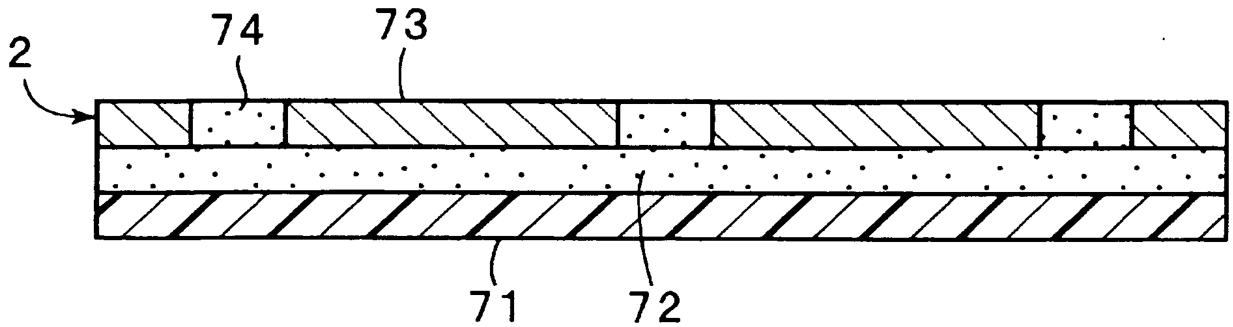
36

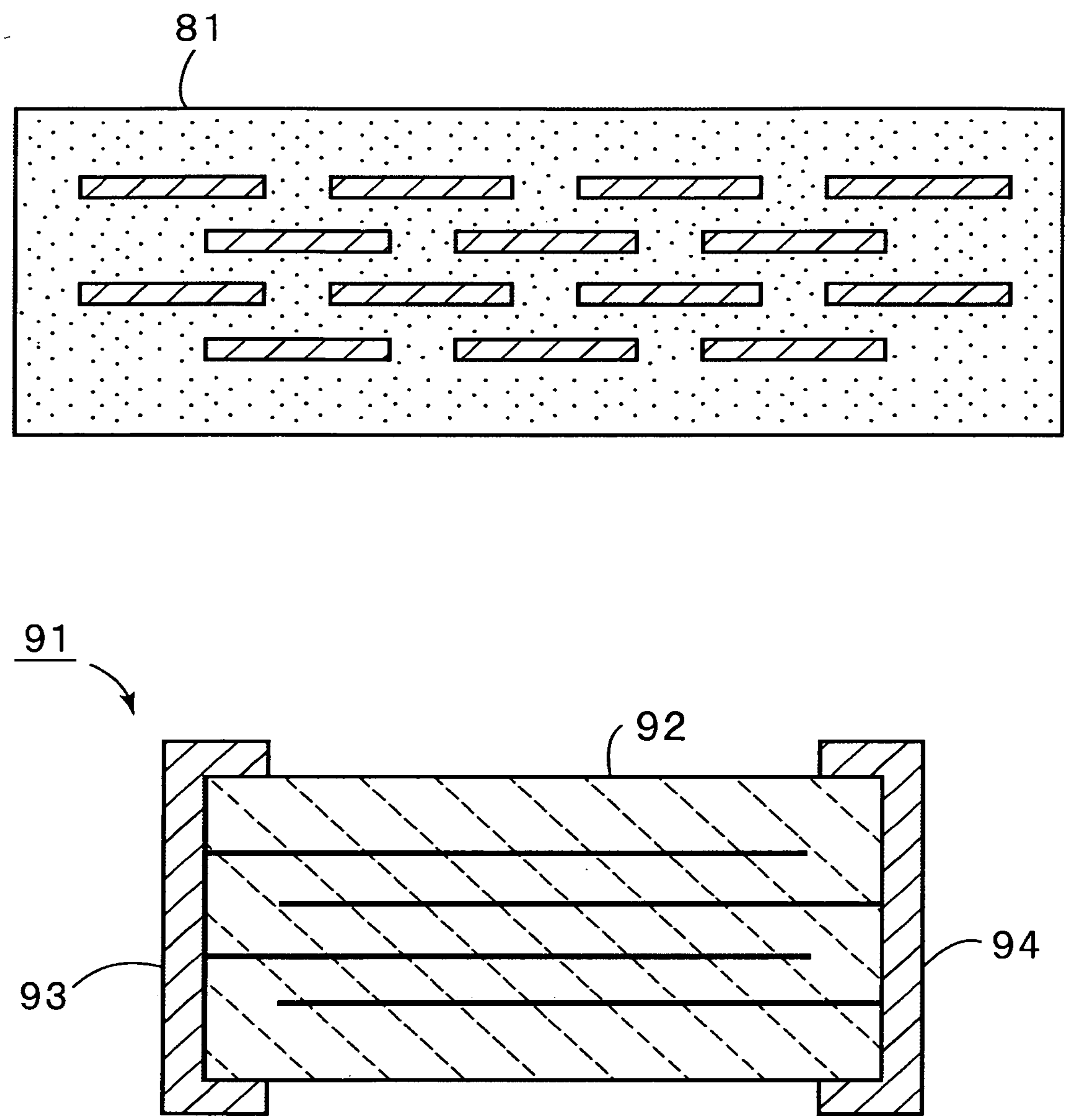
【図８】 [FIG. 8]



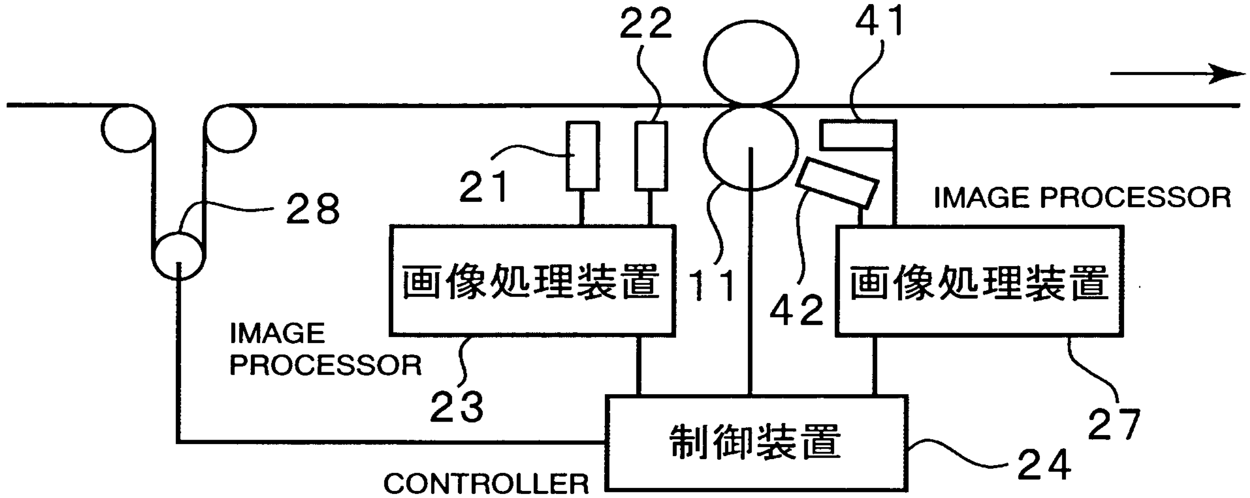
【図９】 [FIG. 9]

（ａ）

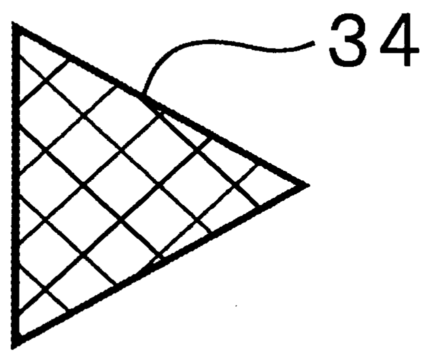
（ｂ）



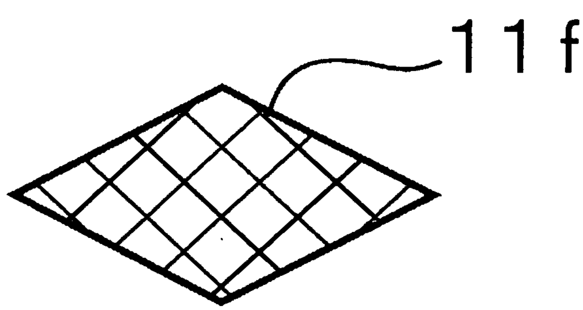
【図１０】 [FIG. 10]


22
41
21
28
IMAGE PROCESSOR
画像処理装置
11
42
画像処理装置
IMAGE
PROCESSOR
23
27
制御装置
24
CONTROLLER

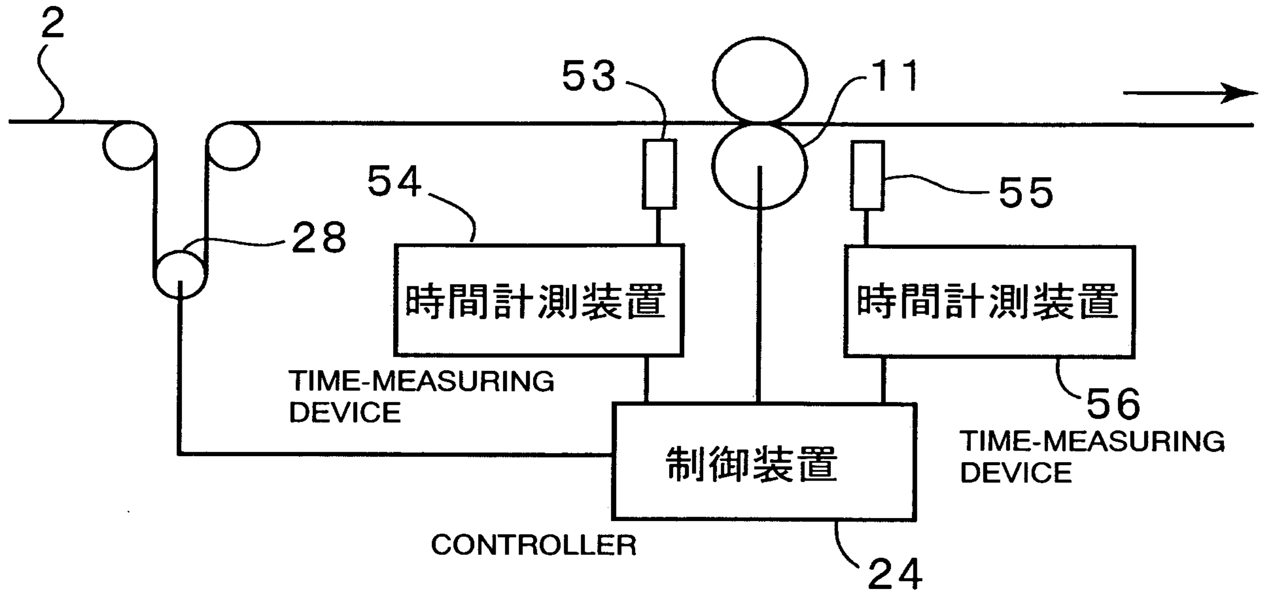
【図１１】　[FIG. 11]



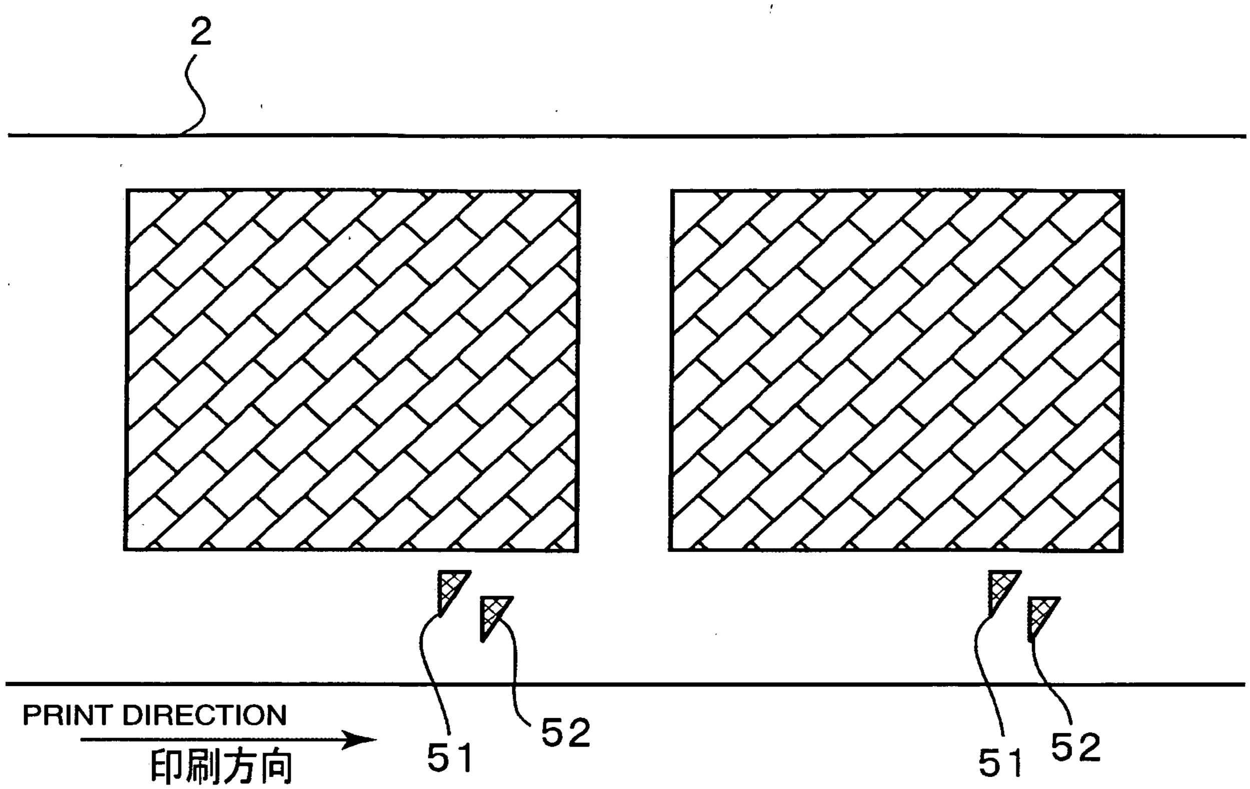
【図１２】　[FIG. 12]



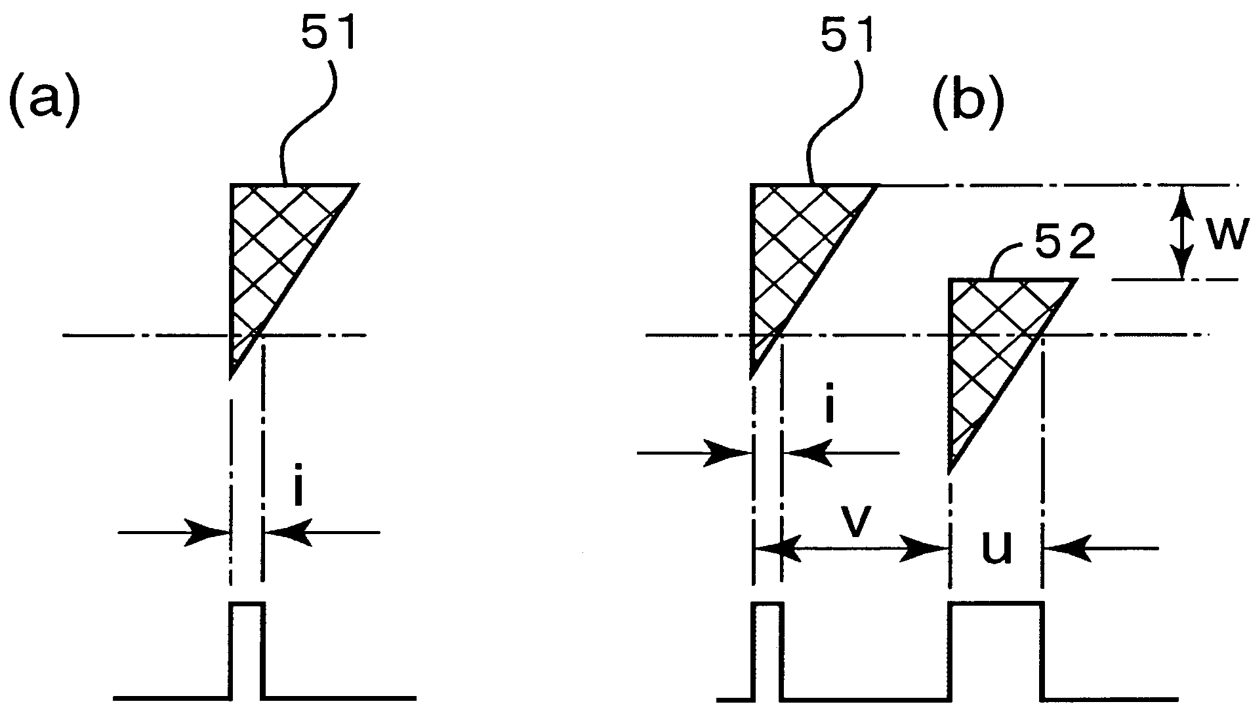
【図１３】 [FIG. 13]


2
53
11
54
55
28
時間計測装置
時間計測装置
TIME-MEASURING DEVICE
56
TIME-MEASURING DEVICE
制御装置
CONTROLLER
24

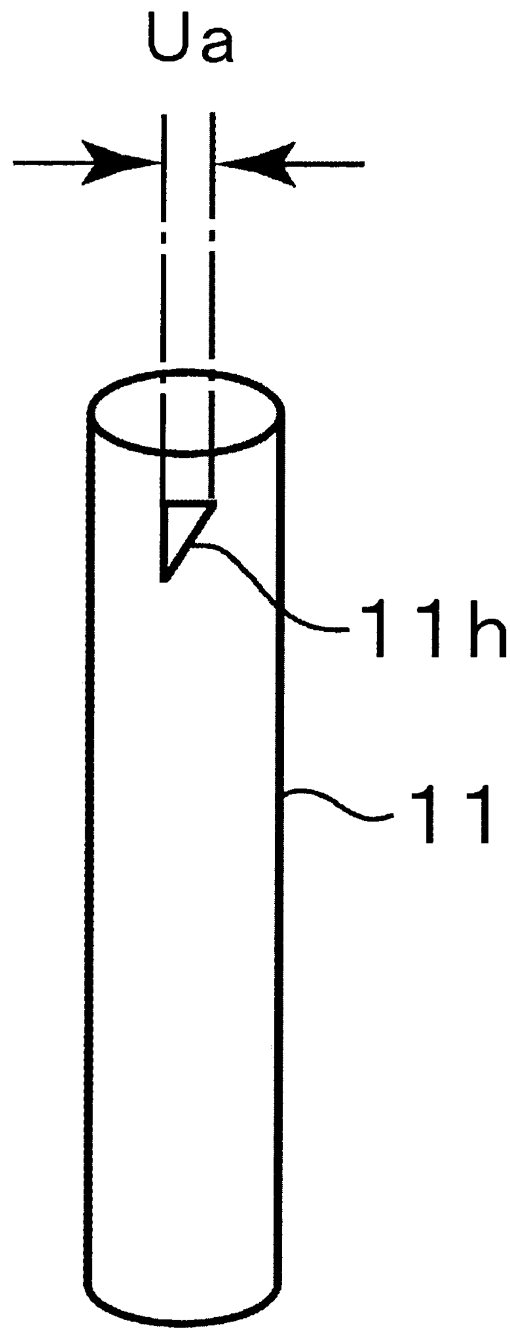
【図１４】　[FIG. 14]



【図１５】　[FIG. 15]



【図１６】 [FIG. 16]



【図１７】 [FIG. 17]